THE RESPONSIBILITY OF INDUSTRY, THE UNIVERSITIES AND GOVERNMENT IN FINANCING RESEARCH AND THE TRAINING OF RESEARCH PERSONNEL

Talk by Dr. Byron T. Shaw, Administrator, Agricultural Research Administration, U. S. Department of Agriculture, before the Seventh Conference on the Administration of Research in Berkeley, California, September 2, 1953.

World War II awakened the public to a realization of how greatly national survival is now dependent upon scientific research, but the years since have only accentuated the questions of how we should use it, and who should pay for it.

Policies involved in the support of scientific research have come up everywhere for discussion and study. Educational and industrial concern has been manifest from every direction. The American Council of Education, the American Association for the Advancement of Science, the National Academy of Science, the National Research Council, the National Science Foundation, and virtually all engineering and scientific societies have probed many aspects.

The Federal Government, through the Office of Defense Mobilization and other agencies, has given deep consideration to the problems involved.

The various studies make clear that facilities and trained manpower constitute potential bottlenecks which may constrict future technological development; that the expanding research requests upon universities pose the problem of creeping encroachment upon their education work; and that careful measures are vital, so the pressing nature of the research needs will not result in unwise and unproductive policies or actions, whether in the universities, in industry, or in Government.

It is clear, too, that better support of scientific progress is essential to national progress. Both President Eisenhower and Secretary of Agriculture Benson have, in public addresses, emphasized the importance of developing new knowledge and new methods for the utilization of national resources.

The financing of research and of the training of research scientists is the particular aspect we discuss this morning.

In exploring this question, it first becomes necessary to consider just what it is we are trying to finance. The boundaries we set in defining research make a tremendous difference in the costs involved.

Science begins with "basic" research, the discovery of new fundamental facts, laws, and principles. Science continues through applied research, the application of these laws to the discovery of how they may be made useful to mankind. The next step is development, the translation of applied science into equipment, processes, and methods. This must be followed by design and production engineering, of both the need equipment for utilizing research and the physical facilities for the manufacture of such tools.

The National Science Foundation * has reported that Federal funds for "research and development" amounted to 2.2 billion dollars during the fiscal year ending June 30, 1952. The largest part of this sum was for development. I note that "development" is not included in the title of this conference, which is given as "The Administration of Research."

In discussing the responsibilities of Government and the universities it might be possible to make a distinction between "research" and "development." Universities are normally concerned with basic and applied research, and only under exceptional circumstances and at the request of the Government or their constituents do they get into development. The Government is interested in both research and development, and while the line between them is somewhat hazy, we could perhaps make a distinction between those Federal funds utilized for research and those that go into development.

This conference is, however, concerned not only with the universities and Government, but also with the place of industry in this problem, and industry is

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* Federal Funds for Science - I. Federal Funds for Scientific Research and Development at Nonprofit Institutions - 1950-1951 and 1951-1952, National Science Foundation

primarily concerned with development. An industrial corporation must so manage its business that its income will cover not only its operating costs, but also provide dividends to the stockholders. Only such research as is carried eventually through the development stage to production can directly provide such income.

In considering the relationship between the Government, the universities, and industry in the question of finance, it becomes necessary to examine the entire range of research and development. We can then see how it can be broken down into parts.

RESEARCH BY THE FEDERAL GOVERNMENT

The beginning of research in the Federal Government dates from the establishment of the Department of Agriculture in 1862. At that time Congress directed the Commissioner of Agriculture to acquire information "...by means of practical and scientific experiments" and "by the collection of statistics."

Earlier in the same year the Congress enacted legislation which ceded large tracts of public land for the endowment of at least one college in each State to teach agriculture and the mechanic arts. This was the beginning of our great system of land-grant colleges and universities.

Very early in their history the new agricultural colleges came face to face with the fact that they had little accurate and scientific knowledge of agriculture. Some States, therefore, began establishing experiment stations as part of the agricultural colleges, with the duty of obtaining this knowledge.

Federal financial assistance was soon forthcoming. In 1887 the Congress passed the first of several Acts making grants to the States. The first allotment amounted to $15,000 for each State to help establish and support an experiment station as a department of the agricultural college in that State. Federal support has continued to increase through the years. At present, about one-fifth the total funds of State experiment stations comes through these

Federal grants, which for the current year amount to 13-1/2 million dollars.

Because of these Federal grants and because of the common objectives, a close working relationship has always existed between the Department and the State experiment stations. The Office of Experiment Stations, a constituent agency of the Agricultural Research Administration, administers the Federal grants and thus serves as a link between research in the Department and that in the States. In recent years, this bond has been strengthened through regional groups of station directors, who plan their work jointly with representatives of the Department. The State stations and the Department together form the largest network of cooperating agricultural research agencies anywhere in the world, with 12,000 scientists.

The annual public expenditures for agricultural research, State and Federal, are now approximately 113 million dollars. About 78 percent of these funds is spent on production research, with the remainder going to utilization and marketing research.

Under the provisions of the Research and Marketing Act of 1946, the Department of Agriculture is in more or less continuous consultation with certain advisory committees. The group with the widest responsibility as to Department policy is known as the Agricultural Research Policy Committee. It consists of 11 members representing various fields of production, distribution, and utilization.

During the past 2 years this committee has been taking a forward look at the anticipated population, food needs, and potential production for the next 20-odd years. It calls attention to the impressive fact that unless there is further advance in knowledge, and improvement in farm management, the crop acreage in the United States will not be able to produce enough to feed the estimated population in 1975 on a dietary level as high as today.

Studies show that to maintain our present living standards in 1975 with farm production remaining at current rates, at least 115 million more acres of productive area will be required than is now available for food production. Part of this additional land can be supplied. Possibly 15 million acres now being used for the feeding of horses and mules will become available for food production as the number of these animals declines still further. Perhaps an additional 30 million acres can be brought into cultivation by irrigation and drainage. Nevertheless, there still would be a shortage of at least 70 million acres of the total increase required in productive land.

It is obvious that agricultural research must help to fill this gap.

Agriculture accounts for less than 3 percent of the 2.2 billion dollars of Federal expenditures for research and development. The committee is recommending substantial increases in the level of agricultural research carried out by the States and the Federal Government. The Department has been analyzing the implications of this recommendation from the standpoint of facilities and scientific personnel that will be required and are likely to be available.

RESEARCH BY INDUSTRY

In its historical development, research in industry followed that in the Federal and State Governments. According to the National Research Council, the first company to organize industrial research as a separate activity was General Electric, which founded its famous laboratory in 1900. Bell Telephone, Westinghouse, and Dupont all began research in the first decade of this century and were followed soon by many others. By 1930 industry was spending more for research than Government and the universities combined.

The Bureau of Labor Statistics of the Department of Labor,* in 1952 obtained estimates from some 2,000 industrial concerns on their expenditures for research and development. The total amounted to nearly 2 billion dollars in 1951. About 1 billion of that amount came from Federal Government agencies; the other billion was derived from the normal non-Government income of the companies themselves. The 2-billion dollars represent about 2 percent of all their sales receipts. ranging in different industries from about 1/3 of 1 percent in food and kindred products to 12.7 percent in the case of aircraft.

It is estimated that currently industry spends 140 million dollars a year for research on agricultural and forestry products and on machinery and materials used in agriculture and forestry. This estimate is based on figures included in the report of the Bureau of Labor Statistics, in addition to certain data collected by our own Department, and other figures obtained from the National Research Council.

Of this amount, about 50 million dollars is in direct aid to agricultural and forest production. Most of this is for farm machinery research, which involves expenditures by industry of more than 20 million dollars, and research on agricultural chemicals, which costs industry about 25 million dollars.

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* "Industrial Research and Development - A Preliminary Report," Bureau of Labor Statistics, Department of Labor, and Research and Development Board, Department of Defense - January 1953.

This report states that the total amount reported by 1,934 companies was $1,959,100,000 of which 47 percent came from the Government. This would leave $1,038,293,000 as expended from the companies' own funds. Included in these figures are reports from 281 commercial consulting services, 37 non-profit research agencies, and 89 other non-manufacturing concerns. The total for the non-manufacturing agencies was $170,169,000 for 1951. The companies were asked not to include expenditures for "quality control, product testing, market research, sales promotion, sales service, and research in the social sciences and psychology."

The remaining 90 million dollars is spent by industry on research to develop new and improved products and methods of handling them. About 40 million of this is spent on food and related products; 36 million on forest products; and 12 to 13 million on agricultural textiles, tobacco, and miscellaneous products.

Secretary Benson has recently pointed out that, "The industries that are currently spending 140 million dollars on agricultural research have found it profitable. ...When agricultural products are used as raw materials, we are using a renewable resource. ...As our population grows, we will have more concern about non-renewable resources. We should be exploring raw material sources in agriculture more vigorously than we are. Every time industry finds a new use for an agricultural product, it helps industry, it helps agriculture, and it helps the Nation."

UNIVERSITY RESEARCH

Most of the more expensive types of research carried on in universities are now financed under Government grants and contracts or under cooperative agreements with industrial concerns. I have no data covering current university expenditures for research from their non-Government and non-industrial income. In 1947, the President's Scientific Research Board reported the level of such expenditures by educational institutions as 45 million dollars. This figure now is certainly too low, as Department data indicate that the Land-Grant Colleges spent $56,883,853 in fiscal year 1952 on agricultural research alone, over and aobve the amounts obtained from the Federal Government under the grant acts.

COMMENTS

The total national outlay for scientific research and development in 1952 from Government, industry, and university sources is believed by the Bureau of Labor Statistics to be of the order of 3-1/2 billion dollars. This includes estimates concerning those industrial concerns that did not file reports.

The sponsors of this conference doubtless did not expect any speaker to make a pronouncement as to whether the current distribution of the costs between the Federal Government, industry, and educational institutions is the best in the long run. The Bureau of the Budget would like very much to work out a basis for obtaining an over-all answer to this question.

In discussing the subject of research financing, let us have no illusions as to the ultimate source from which these funds are coming. The only source of research funds is the general public. In the case of universities, this public support comes primarily through State and municipal taxation and through voluntary contributions. In the case of Federal financing, the routing is primarily through taxation of corporations and of private incomes. In the case of industry, the costs are necessarily included in the price of the products and services sold, and are accordingly paid by the customers.

The place of industry in financing research has been greatly modified during recent years by the provisions of Federal income tax laws. Research expenditures are recognized as corporate expenses and accordingly as deductions from income before the levy of corporation taxes. This has made it possible for corporation management to view research expenditures on an entirely different economic basis than before. Corporate taxes may approximate

half of net operating revenue, and the individual income tax of large corporation stockholders may reach 70 or 80 percent of the dividends paid to those stockholders. Corporation boards of directors have, therefore, very appropriately been deciding in many cases to make large, long-term corporate investments by devoting a substantial part of their gross income to research.

Regardless of these considerations, it seems to me that industrial concerns are justified in setting up one over-riding criterion for their research and development expenditures. It is the ultimate enhancement of the position of the corporation and the anticipation of either present or future (perhaps distant future) profits.

Industry's first concern is development. This will continue to encourage emphasis on the solution of applied research problems on which development and engineering projects are based.

In the case of large industrial concerns engaged in manufacturing products in new fields, such as aeronautics and electronics, I feel that they will inevitably get more and more into basic research as well. In attempting to utilize fundamental knowledge for applied research, these concerns are sure to find, as the automotive industry found some years ago, that their progress is limited by the frontiers of basic science. In some cases where they have "leads" as to the basic physical and biological problems needing solution, they will have to subsidize public institutions with appropriate personnel and facilities to find the answers for them.

The level of financing will not, I believe, be determined by any magic formula based on responsibility.

Educational institutions will be able to finance only a small proportion of basic research out of their own resources. Their ability will be governed by State appropriations and voluntary contributions for this purpose, which will augment what can be done conveniently by their instructional staff members, part or full-time assistants, and graduate students. This is likely to be the least expensive, but perhaps most productive, feature of the whole national research program. It is likely to be concerned largely with basic studies engaged in ferreting out the laws upon which the universe operates. To a large extent it will provide the foundation on which all other scientific advancement will be based.

Industry can be expected to continue making investments in applied research and development. Executive management certainly realizes that such investments are productive from the standpoint of the long-time dividend position of the company. Judgment in this respect will probably vary somewhat from year to year. It will depend first on the public demand for new devices, and second on the economic influences of income tax regulations, Government procurement, and similar factors.

Government will inevitably have to bear the brunt of the cost of research with objectives of two main kinds:

First, problems needing solution for the benefit of the public as a whole, such as those relating to health, agriculture, and natural resources.

Second, research required for the carrying out of strictly Government functions, such as military, post office, and census needs, and the regulation of interstate commerce.

Undoubtedly there will continue to be an interaction between industrial and Government financing whenever industry voluntarily undertakes studies that result in benefit to the general public along health, sanitary, and agricultural lines. To that extent industry will thereby relieve Government of the necessity of making studies in these same fields. Industry, on the other hand, can be expected to

watch closely the results of Government research. It will apply and develop those profitable to the industry.

TRAINING

The subject assigned to the speakers this morning involves two rather different topics. The first, which I have been discussing thus far, relates to the financing of research programs; the second concerns financing the training and education of scientific personnel.

In financing education, we must consider not only the three sources of funds already referred to, namely, the universities, industry, and Government, but we must also bring in the individual being trained.

Traditionally in this country, the financing of a student's subsistence expenses throughout his period of education has been the responsibility of the individual and his family. Changes in economic conditions have made this much more difficult, particularly with respect to advanced training. Studies by the National Research Council* indicated in 1951 that 20,847 of the 39,800 natural science graduate students were financing their studies through teaching and research assistantships and non-Government fellowships and scholarships. Certain services are rendered to the institution in the case of assistantships and occasionally under fellowships also. At least 8,100 out of the remaining 19,000 were being aided through Federal grants to veterans and various types of Government allotments and awards. It is believed that less than 10 percent of the students in graduate schools are now able fully to finance their advanced study themselves from income and savings derived from sources outside the graduate school.

However, we are concerned here not so much with the needs and desires of the individual for advanced education and the possibility of his assuming the cost himself, as we are with public requirements for scientific leadership and

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* National Survey of Graduate Students in the Natural Sciences - November 1, 1951. National Academy of Sciences - National Research Council (Mimeographed).

advancement. These public and industrial requirements have now reached a high level, both in quantity and essentiality. The supply of research workers no longer can be left to the chance that individuals will be able to finance their own training. The public and industry not only need an adequate total supply of graduates, but scientific research requires an unusual level of mental competence. Some assurance is needed that a high proportion of those going into graduate study include the most able members of the population.

The National Manpower Council, on May 18, 1953, reported to President Eisenhower that the country must contribute more financial aid to higher education if it wants to avoid a continuation of present serious shortages of trained scientific and professional personnel.

The shortage of "brainpower" is already acute, and unless there is a concerted national effort it will become steadily worse. To quote from the report: "Only a purposeful and sustained effort can insure that the United States will have adequate resources of scientific and professional manpower to meet its needs. Neither reliance upon a single course of action nor the pursuit of separate and unrelated policies will enable the Nation to attain this goal."

We have found in Agriculture that difficulties in obtaining the specialists we need may arise in two different ways:

First, from an over-all tight personnel situation in the given occupation throughout the United States.

Second, where the proposed program would require more specialists than the total being trained, or such a large proportion of those being trained that the Department and experiment stations could scarcely expect to have their requirements met.

The first of these is illustrated by the situation in engineering. The current total demand for civil, chemical, and mechanical engineers in industry and Government is greater than the supply. The number that is likely to be needed

in agricultural research, outside of strictly agricultural engineering, is only a small fraction of the total. It is less than 1 percent in most engineering specialties. But the tight personnel situation in the general field means that the competition with industry might be severe.

The second is typified by specialties such as those performed by entomologists, plant pathologists, nematologists, and research veterinarians. In these cases, most young bachelor-of-science graduates are not equipped to undertake the solution of research problems. The number of persons pursuing graduate study in the basic sciences that provide the foundation for these specialties is so small that the needs of the anticipated agricultural program can scarcely be met from the supply that is now in sight.

It is believed that this latter class of shortages could be filled first, by increasing the number of available graduate fellowships; and second, by supplying information to educational institutions that will show the increasing demand for specialists in these fields.

The most frequent stipends of research fellowships, scholarships, and assistantships range from $1,000 to $1,600 for the students' subsistence expenses, in addition to such provisions as are made for covering tuition costs. The National Science Foundation fellowships are maintained at approximately this same level, but with a substantial additional amount for dependency allowances and tuition.

If this represents the average cost of graduate study, the total expenditures for subsistence and tuition of 40,000 graduate students in this country would be between $60,000,000 and $80,000,000. This would not cover the maintenance of family dependents. After the termination of the veterans' educational program, presently available assistantships, fellowships, and similar awards (including $1,500,000 in Federal funds administered by the National Science Foundation), are believed to cover a little over half these needs.

So far, the United States has not faced the implications of this situation or established any broad public policy with respect to it.

The expenses of the student are only a small part of the cost of graduate education. Providing faculty and facilities in the universities is considerably more expensive.

The administrative officers of universities unavoidably face the problem of finding ways to finance the costs of faculties and facilities. I do not believe that they should, in addition, be burdened with the necessity of working out methods of financing the living expenses of graduate students. They can administer such outside fellowships as are made available to them, but should not find themselves under the necessity of raising funds for these living expenses.

If that thesis is correct, a substantial part of the future costs of the subsistence and tuition expenses incurred by graduate students in this country must be borne by industry and Government.

The term "industry" of course, does not refer to a single entity, but instead covers thousands of entirely independent corporations organized for profit. Each corporation must examine this problem with respect to its own field of business. Each industrial concern can and perhaps should be expected to finance this problem roughly in proportion to the benefits it receives through the availability for employment of those finishing graduate study.

Many large corporations have been supporting graduate fellowships. They have also been employing certain graduate students for work on the solution of the company's specific industrial problems. I look for industrial participation in graduate study along these lines to continue and expand.

In addition to the general support of graduate study throughout the country, both industry and Government face another type of problem that is steadily becoming more pressing. This is the one commonly known as "in-service training."

Large numbers of young people are recruited for technological work at a fairly early stage in their education. Many of these are found to have potential ability, but need further education and training if they are to become of maximum value to the industrial or Government agency by whom they are employed.

The advantage of stimulating the further education of such employees has long been apparent, but both industry and the Government have been moving very slowly in the direction of assuming that expense. For some years the military agencies have had authority to assign officers to duty at educational institutions for carrying on advanced study and investigations that will increase their value to the agency. Since 1944 the Surgeon General has had somewhat similar authority with respect to Public Health Service employees. Congress has at various times considered extending similar privileges to other agencies.

Congress has been hesitant, nevertheless, to authorize the payment of salaries to persons while they are engaged in graduate study for the purpose of increasing their own competence. This hesitation is partly, but not entirely, due to recognition that some students could seek private employment after completing their "in-service" training at the expense of the Government agency.

Persons who have, at much expense and sacrifice, succeeded in financing their own training and that of their families tend to look askance at the assumption by the Government of financial responsibility for the education of its employees. Similarly, those who had to discontinue their education for financial reasons at an earlier educational level than they would have liked, are often not now enthusiastic about the use of public funds for assuming the burden that has traditionally fallen on the individual and his family.

Thus, the second question that I was asked to answer may be expressed as, "Who should pay for the training of research scientists?" I am inclined to summarize my answer to that question in this way:

University administrators will continue to have the responsibility of raising funds for the provision of faculty and facilities for advanced training. Industry should assume somewhat more of the direct costs of supporting the students themselves than it has heretofore, to the extent that the individual industrial concern can benefit from such advanced studies and that it needs to employ the graduates of such institutions.

The State and Federal Governments are likely to find it necessary to provide increasing public funds for the selection of those college students best adapted to advancing in scientific research, and their maintenance in institutions of advanced study. Government will increasingly find that such training is necessary to enable the agencies to carry out the jobs they are called upon to do.